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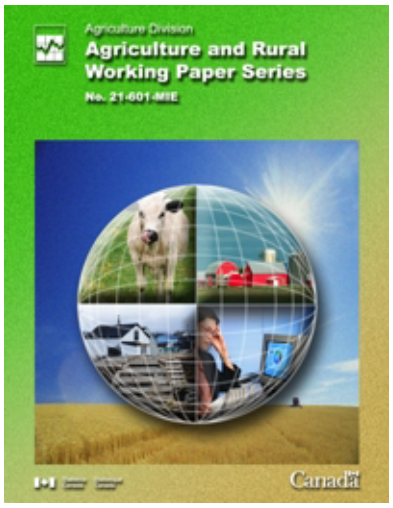
Research Paper

Genetically Modified Grain Corn and Soybeans in Quebec and Ontario in 2000 and 2001



by Bernard Hategekimana

Agriculture Division
Jean Talon Building, 12th floor, Ottawa, K1A 0T6

Telephone: 1 800-465-1991

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Prepared by
Bernard Hategekimana
Crops Section, Agriculture Division, Statistics Canada

Statistics Canada, Agriculture Division
Jean Talon Building, 12th floor
Tunney's Pasture
Ottawa, Ontario K1A 0T6

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Genetically Modified Grain Corn and Soybeans in Quebec and Ontario in 2000 and 2001

Highlights

- Total area of both genetically modified (GM) grain corn and soybean crops rose significantly in Quebec and Ontario in 2001 compared with 2000.
- The increase in GM soybean area was higher than that of GM grain corn.
- The abandon rate of GM was higher for grain corn than for soybean.
- Most of the increased GM area was in Quebec.
- The proportion of large farms reporting GM grain corn or soybeans increased more than any other farm size category.
- Yields for GM soybeans and grain corn were better than yields for non-GM crops in both cases.

Abstract

This report focuses on the changes in the area of genetically modified (GM) grain corn and soybeans, comparing the year 2001 with 2000. In the 2001 growing season, total GM area increased significantly for both GM grain corn and soybean crops in Quebec and Ontario. The number of large farms seeding GM crops rose considerably, while the number of small- and medium-sized farms growing GM crops was quite unchanged.

The increase in GM soybean area was higher than that of GM grain corn. Farms growing both corn and soybeans made the biggest contribution to the increase. The increase appears to be a consequence of both higher average area of GM crops grown per farm by farmers who grew GM crops in 2000 and, to a lesser extent, the adoption of GM technology by new farmers.

Most of the increased GM area was in Quebec, where the area seeded to GM grain corn rose 30.3% and to soybeans, 63.0%. In Ontario, the increase was 11.3% for grain corn and 25.4% for soybeans. In both provinces, the greater GM area for soybeans was more than double the increase in GM area for grain corn.

In Quebec and in Ontario, the proportion of GM grain corn and soybean area to total grain corn and soybean area has increased significantly. In Quebec, GM area accounted for 31% of grain corn area and 27% of soybean area in 2001 compared to 27% and 17% respectively in 2000. In Ontario, the proportions were 29% for grain corn and 23% for soybean in 2001 compared to 27% and 17% respectively in 2000.

In 2001, the proportion of large farms (total operated area greater than 980 acres) reporting GM grain corn or soybeans increased more than any other farm size category. This was especially apparent in Quebec. However, the small farm category, which accounted for the largest proportion of GM area in 2000, saw its share drop significantly in 2001.

Statistics Canada's November Farm Survey data shows that yields for GM soybeans and grain corn have been better than yields for non-GM crops, and that growing GM grain corn and soybeans appears to have improved the average yield for both crops.

Introduction

This paper provides information on the production of GM grain corn and soybeans in Canada. The biotechnology industry has fostered the creation of genetically modifed varieties of grain corn and soybeans in an attempt to develop crops that are able to resist damage by specific pests, fungus or particular herbicides. The purpose of the paper is to describe the adoption of these new crops and provide a basis for further work to analyse economic implications for agriculture.

Around the world, the genetically modified seed (GMS) area increased 11.0% in 2000, from 98.5 million to 109 million acres, with almost all that area found in developed countries in the Northern Hemisphere. But what exactly do we mean by GMS in the case of grain corn and soybeans? With respect to the grain corn and soybeans grown in Canada, the gene pool of seed

from a given variety of grain corn or soybeans has been modified through genetic engineering by the incorporation of a foreign gene from another species or variety, in order to transfer certain qualities or characteristics[1] (Saxena et al, 1999).

Scientists and companies who sell GMS and related chemicals believe that using GM plants, especially those that are resistant to herbicides and insects, is the best means of controlling pests, reducing the use of chemical pesticides and associated costs, and increasing crop yields. Many growers appear to share this opinion, especially as GM plants allow them greater flexibility in agricultural practices. There are, however, fears that useful insects may be affected and eliminated together with the pests in question, and that some of the characteristics may be accidently transferred to weeds that will become more difficult to control.

Cross-pollination from GM crops to non-GM varieties is also a risk, especially where producers are trying to grow non-GM crops to meet the demands of a specific domestic or export market. This is also of particular concern to organic growers attempting to grow non-GM crops. The degree to which cross-pollination may have resulted in the contamination of non-GM crop varieties is unknown, and segregation is technically difficult and costly on the farm, as well as in storage and transit. According to a recent U.S. survey, most growers are not planning on implementing segregation, given the high cost of this operation (*Agriweek,* 2001).

Farmers report that the main reason they grow GM crops is to facilitate farm work. This is an interesting observation; preliminary work suggests that GM crops do not guarantee better yields and that farmers may not capture much in the way of economic benefits from GM crops (Benbrook, 2001)[2]. The requirements imposed by certain importing countries, stipulating that grain must be segregated in the field and during storage and handling, may very well prove difficult for Canadian growers and is a further complication to the future role of GM crops in Canadian agriculture. This study attempts to record farmers' use and acceptance of GM grain corn and soybeans in Quebec and Ontario, as they evaluate the operational efficiency of their operation against the response of the marketplace.

[1] In the case of Bt-corn, the cry1Ab gene from *Bacillus thuringiensis*, which is responsible for producing the precursor of a toxin that kills the European corn borer, has been introduced. When the larvae of this small butterfly eat grain corn that has acquired the gene, the precursor is transformed into a toxin, and they die. The difference between other varieties of Bt-corn and StarLink Bt-corn lies in the fact that the latter contains the Cry9C gene from *Bacillus thuringiensis* subspecies *tolworthi*, which binds to different receptors than the Cry1Ab and CryAc genes. It produces high concentrations of the toxin (10 to 400 times the quantity produced by other varieties of Bt-corn) in all parts of the plant, whereas the toxins produced by other varieties are located mainly in the leaves and pollen. The toxin produced by the StarLink variety of Bt-corn also acts on other insects, while those of other varieties do not. The variety of Bt-corn most commonly grown in Canada is Bt_176, which contains the Cry1Ab gene. The proteo-chemical properties of the Cry9C gene are similar to those responsible for food allergies (allergens) (Rautenberg, Oliver, 2000), and consist primarily of stability in the face of high temperatures (90°C) and resistence to breakdown by gastric juices (Mendelsohn, 2001). The gene in corn and soybean Roundup Ready protects these crops from Roundup (glyphosate), a nonselective herbicide generally used for weed control.

[2] The report found that on average, yield increases due to Bt corn have not increased farm income enough to cover the higher costs of Bt seed. Between 1996-2001, American farmers paid at least $659 million in price premiums to plant Bt corn, while boosting their harvest by only 276 million bushels - worth some $567 million in economic gain. The bottom line for farmers is a net loss of $92 million—about $1.31 per acre.

Methodology

The main goal of this study is to conduct a detailed data analysis in order to establish a profile of growers who sow all or part of their soybean or grain corn fields with genetically modified seed (GMS). At the same time, we planned to evaluate the actual impact of GMS use on crop yields and examine development in seeded area, as well as the process involved in the adoption of GMS as a farm input. The estimates in this paper are based on Statistics Canada farm survey data. Some differences can be found between the estimates used in this paper and the official published statistics, as the official statistics are based upon all available information—the survey estimates are one of those sources.

Our working hypothesis is that growers experiment with and adopt new technologies to meet specific needs and improve performance. To verify the hypothesis, in our previous research we examined the characteristics of farm operations likely to adopt the use of GMS, as well as other traits that these establishments might have in common. We applied logistical models to the data using the Wesvar Complex Samples 3.0 software program. Yield data have been taken from Statistics Canada's November 2000 and 2001 Farm Surveys. For each growing season, data were analyzed using the SUUDAN 7.5 "DESCRIPT" procedure.

In order to assess the differences which can exist among GM farm adopters, we created three size categories of farms. These were determined based on total operated area (TOA) from the June 2000 Farm Survey and 1996 Census of Agriculture data. The small size category's high limit was determined by calculating:

1) the mean of TOA from the June 2000 Farm Survey plus half of the standard error of Ontario and Quebec;
2)and the mean of TOA from the 1996 Census of Agriculture data for the same farms plus half the standard error.

The small size category's high limit (490 acres) has been set at the rounded mean of the results obtained in steps 1) and 2). Consultation with experts in agricultural business management has confirmed that 490 acres is the economic optimum size for many of the commodities in Ontario and Quebec. The high limit of the medium-sized farm category has been set at the double of the high limit of the small farm category. The third category is composed of all farms whose size is greater than the high limit of the medium ones.

In the present work, we evaluate the changes in seeded area and yields of GM crops between 2000 and 2001. The analysis of the 2001 data was complicated compared with that of the 2000 data, as some sample design changes were made in the 2001 farm surveys. The sample design differences introduced some unexpected challenges for the data analysis, particularly the inter year comparisons, as the 2000 and 2001 samples were not independent. To test the difference between the June 2001 and June 2000 estimates, we have had to use different formulas[3] for measuring the variance of the difference between totals and between ratios (Appendix 1).

[3] Formulae adapted by Milorad Kovacevic and Owen Phillips from Methods presented in Roberts et al, 2001, in order to suit a rotating panel design.

Longitudinal weights have been used to compare the status of GM growers during the 2000 and 2001 growing seasons. This allows the pooling of the regression results on the difference between 2000 and 2001 GM area and the difference between 2001 and 2000 non-GM area for farms having both GM grain corn and /or GM soybeans in both growing seasons.

Imputed data has been used in area calculations to adjust for non-response. Average values have been used to impute survey values for missing data to approximate the crop area of farmers who had GM crops but did not report GM area. The impact of this imputation was between 4.0% and 5.5% in 2001 and between 6.0% and 9.6% in the year 2000.

Comparisons of yields were measured in terms of the difference in yields between the two growing seasons and between GM and non-GM crops. The SUUDAN 7.5 "Ratio" procedure and Jackknife[4] variance estimation methods were used to compute yields, means and yield differences for each growing season. To compare GM and non-GM yields, the yield was computed based on the production and the harvested area of GM and non-GM crops. In order to ascertain the impact of GM on global farm yield, farms were divided in three groups. The first group was made up of farms with only GM grain corn or GM soybeans (GM group). The second group consisted of farms with only non-GM grain corn or non-GM soybeans (non-GM group). The third and final group represented farms with both GM and non-GM grain corn areas or GM and non-GM soybean areas. In order to ensure accuracy and confidentiality, analysis at the regional level was restricted to the principal growing regions for both corn and soybean in the two provinces.

[4] The Jackknife is a resampling technique for obtaining design consistent estimates of variance. For more information on the Jackknife, see: Babubhai V.Shah et al, (1997).

The Adoption Phenomena Are Dynamic

1. Farms with both grain corn and soybeans

1.1 Farming in 2001 and 2000

Individual farmer decisions on whether to grow GM grain corn and soybeans and how much to plant differed substantially from 2000 to 2001. In 2001, some farmers increased their GM area while others decreased their GM area or decided not to seed any farmland to GM crops. Of the farmers contacted in both years that had grown both grain corn and soybeans, 34.0% in Ontario and 38.8% in Quebec reported an increase in their area of GM grain corn. Of the same group of farmers, 22.8% in Ontario and 29.2% in Quebec reported larger areas of GM soybeans (Table 1, Figure 1).

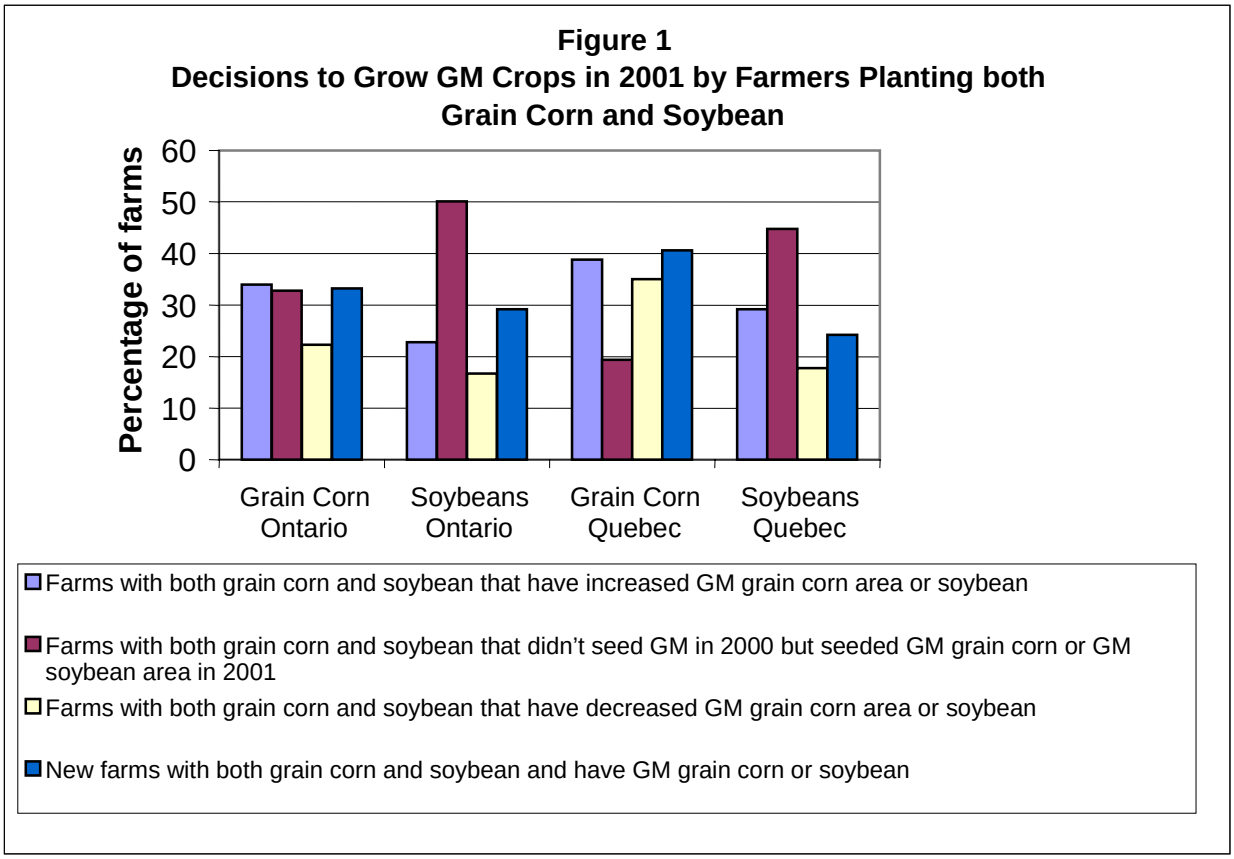
Of the farmers who did not seed GM crops in 2000 but did seed them in 2001, the largest proportion seeded GM soybeans (50.1% in Ontario and 44.8% in Quebec) and a much smaller proportion seeded GM grain corn (32.8% in Ontario and 19.4% in Quebec). Many farmers decreased their area of GM grain corn; a much larger decline than that for GM soybean area (Figure 1).

Some farmers who seeded GM crops in 2000 did not seed GM crops in 2001. In Ontario, the 29.8% of farmers who did not seed genetically modified crops in 2001 were previously GM grain corn growers; and 24.1% were previously GM soybean growers. In Quebec, the percentage of GM farmers in 2000 who did not seed GM crops in 2001 was very similar for both grain corn (24.4%) and soybeans (24.3%).

1.2 Farmers contacted only in 2001

Among the new farmers in the sample who grew both grain corn and soybean, a relatively large percentage seeded with GM grain corn—33.2% in Ontario and 40.6% in Quebec. For soybeans, these percentages were 29.2% in Ontario and 24.2% in Quebec (Figure 1).

Figure 1
Decisions to Grow GM Crops in 2001 by Farmers Planting both Grain Corn and Soybean



Source: Statistics Canada, Agriculture Division, June Farm Surveys, 2000 and 2001.

2. Farms with grain corn or soybeans

2.1 Farming in 2001 and in 2000

In Ontario, 24.5% of GM growers increased their GM soybean area and 18.4% enlarged their GM grain corn area. In Quebec, the comparison is reversed; 26.9% of GM growers increased their GM grain corn area, but only 13.5% seeded a larger area to GM soybeans (Table 1, Figure 2).

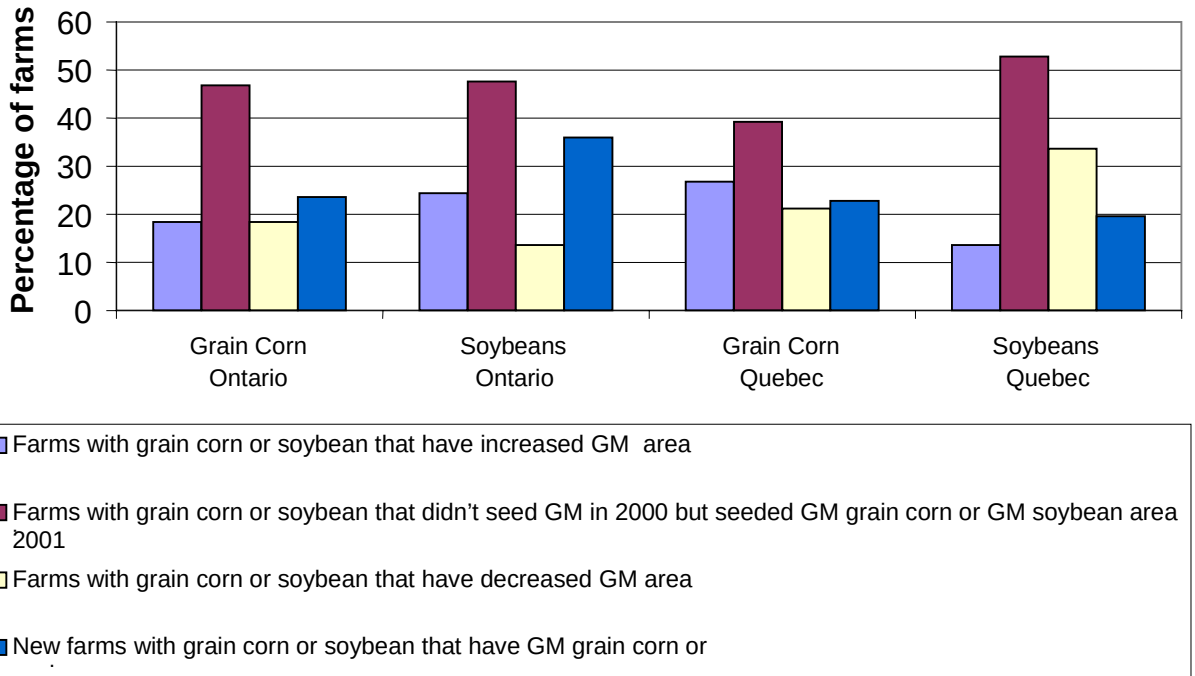
Among Quebec farmers who did not grow GM crops in 2000 but planted GM in 2001, 52.7% chose soybeans and 39.4% grain corn. In Ontario, the percentage of farmers who seeded their first GM crop in 2001 was nearly equally divided: 46.9% grain corn and 47.8% soybeans.

Of Quebec farmers who devoted less farmland to GM crops, 33.8% decreased their GM soybean area but 21.1% decreased their GM grain corn area. Of Ontario farmers who planted less area with GM crops, 18.6% reduced their GM grain corn area compared with 13.5% who decreased their soybean area. In Quebec, 30.1% of farmers who reported growing GM grain corn in 2000 grew none of it in 2001. Of those who grew GM soybeans in 2000, 10.2% grew none in 2001 (Table 1, Figure 2).

2.2 Farmers contacted only in 2001

Among Ontario farmers who reported for the first time in 2001, 36.0% grew GM soybeans and 23.8% grew GM grain corn. In Quebec, 22.7% of the newly contacted farmers grew GM corn and 19.8% GM soybeans (Table 1).

Figure 2
Decisions to Grow GM Crops in 2001 by Farmers Planting Grain Corn or Soybeans



Source: Statistics Canada, Agriculture Division, June Farm Surveys, 2000 and 2001.

Of all Ontario GM growers who were contacted in 2000 and again in 2001, those who seeded both grain corn and soybeans accounted for 74.1% of the GM grain corn area and for 69.5% of the GM soybean area in Ontario. In Quebec, those percentages were 55.4% for grain corn and 83.7% for soybeans.

In 2001, as shown in the figures below and in Table 1:

- GM soybeans were favoured by farmers who seeded both grain corn and soybeans but did not seed GM crops in 2000. This was particularly apparent in Quebec.
- More farmers with both grain corn and soybeans decided to increase their GM grain corn area. Among those who decided to reduce their GM area, the majority chose to decrease GM grain corn rather than GM soybeans.
  More farmers with GM grain corn in 2000 abandoned it in 2001 than did those with GM soybeans.

- Farmers in Quebec and Ontario showed different GM adoption patterns. In Ontario, only a slightly larger proportion of farmers seeded GM grain corn than GM soybeans. In Quebec, however, farmers expressed more interest in GM soybeans than in grain corn. This may be explained by the different experiences with those two crops. Soybeans are a relatively new crop in Quebec compared with Ontario. More new farmers who seeded both GM grain corn and GM soybeans preferred to plant GM grain corn than GM soybeans. However, among farmers who decided to grow GM grain corn or GM soybeans, GM soybeans was the preferred crop, especially in Quebec.
- In Ontario, among farmers with only grain corn or soybeans, a relatively large number of those who seeded GM soybeans in 2000 increased their GM area in 2001. In Quebec, it was the case for farmers who had seeded GM grain corn in 2000.
- In Quebec, among farmers who grew only non-GM grain corn or soybeans in 2000 but tried GM crops in 2001, more chose GM soybeans than GM grain corn.

The results suggest that GM technology is still being adopted. However, according to the industry, corn borer damage was substantial in Ontario in 1999. Some industry analysts speculate that this may have encouraged more farmers to experiment with GM grain corn in 2000. Because corn borer damage was noticeably less severe in 2000, farmers may have been persuaded to continue to expand their GM area.

Table 1. Percentage of GM Growers by Commodity and by Farm Category for Different Decisions

	Ontario		Quebec	
	Grain corn	Soybean	Grain corn	Soybean
1. Have sown both grain corn and soybeans				
Farms with both grain corn and soybeans that have increased GM grain corn area or soybeans	34.0	22.8	38.8	29.2
Farms with both grain corn and soybeans that didn't seed GM in 2000 but seeded GM grain corn or GM soybeans area in 2001	32.8	50.1	19.4	44.8
Farms with both grain corn and soybeans that have decreased GM grain corn area or soybeans	22.3	16.7	35.0	17.8
Farms with both grain corn and soybeans that have planted GM in 2000 and not in 2001	29.8	24.1	24.4	24.3
Farms with both grain corn and soybeans only that have seeded the same GM area	4.4	4.6	3.0	1.5
Farms with both grain corn and soybeans that didn't report GM area	6.4	5.9	3.8	6.7
Total 11	**100**	**100**	**100**	**100**
New farms with both grain corn and soybeans that have GM grain corn or soybeans	33.2	29.2	40.6	24.2
New farms with both grain corn and soybeans that have no GM grain corn or soybeans	64.4	67.1	55.1	71.6
New farms with both grain corn and soybeans that didn't report GM area	2.4	3.6	4.3	4.2
Total 12	**100**	**100**	**100**	**100**
2. Have sown grain corn or soybeans				
Farms with grain corn or soybeans that have increased GM area	18.4	24.5	26.9	13.5
Farms with grain corn or soybeans that didn't seed GM in 2000 but seeded GM grain corn or GM soybeans area in 2001	46.9	47.8	39.4	52.7
Farms with grain corn or soybeans that have decreased GM area	18.6	13.5	21.1	33.8
Farms with grain corn or soybeans that have GM area in 2000 and no GM area in 2001	25.1	22.6	30.1	10.2
Farms with grain corn or soybeans that have the same GM area	1.7	0.0	2.3	0.0
Farms with grain corn or soybeans that didn't report GM area	14.5	14.2	10.3	0.0
Total 21	**100**	**100**	**100**	**100**
New farms with grain corn or soybeans that have GM grain corn or soybeans	23.8	36.0	22.7	19.8
New farms with grain corn or soybeans that have no GM grain corn or soybeans	67.2	61.8	73.0	69.9
New farms with both grain corn and soybeans that didn't report GM area	9.0	2.2	4.3	10.4
Total 22	**100**	**100**	**100**	**100**

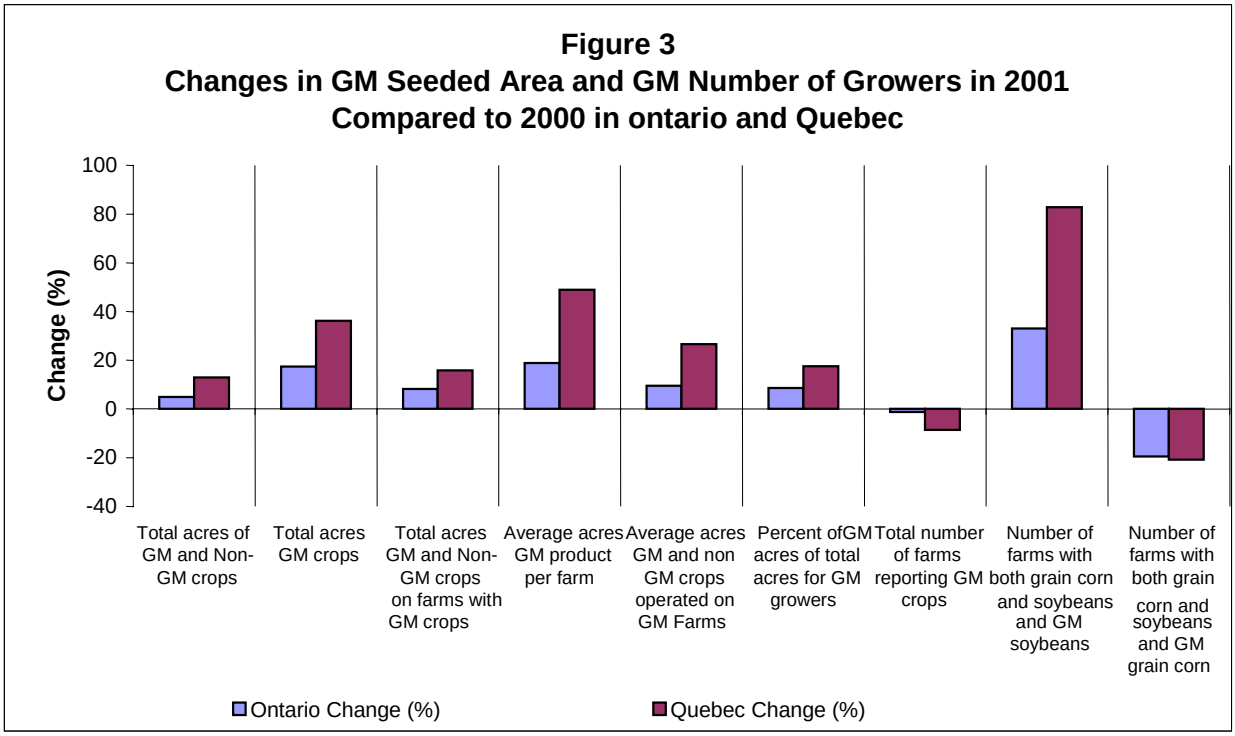
Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

General Profile

In Quebec and Ontario, the total area of GM grain corn and soybeans continues to increase, increasing the proportion of grain corn and soybeans seeded to GM varieties. Surprisingly, the number of farmers growing GM grain corn and soybeans are declining as the crop area continues to increase. This implies that there is a significant per-farm increase in GM seeded area among those that are choosing to remain as GM growers. Farmers that normally grow both grain corn and soybeans are making the most significant contributions to the increases in GM grain corn and soybeans (Table 2, Figure 3).

The number of farms growing grain corn and soybeans and reporting GM area for both crops increased, but not significantly. The number of farms growing grain corn and soybeans but reporting only GM area for grain corn fell sharply in Quebec and Ontario. However,

in both provinces the number of farms growing only GM soybeans grew significantly (Table 2, Figure 3).



Source: Statistics Canada, Agriculture Division, June Farm Surveys, 2000 and 2001.

The number of farmers growing only grain corn and reporting that they grew GM grain corn decreased in both Ontario and Quebec.

Table 2. Changes in Total GM Farms in Ontario and Quebec

	Ontario					Quebec				
	2000	**2001**	**Change**	**T-test**	**P-value**	**2000**	**2001**	**Change**	**T-test**	**P-value**
Total area	1,877,970	1,972,108	5.0	2.79	***	973,371	1,099,917	13.0	2.11	**
Total acres of GM products	918,207	1,079,057	17.5	4.78	***	317,639	432,821	36.3	1.6	*
Total number of farms reporting GM products	10,632	10,507	-1.2	0.36	ns	3,463	3,166	-8.6	1.58	*
Number of farms with both grain corn and soybeans and GM grain corn and soybeans	2,362	2,553	8.1	1.08	ns	615	685	11.4	0.78	ns
Number of farms with both grain corn and soybeans and GM grain corn	2,941	2,371	-19.4	3.26	***	1,202	952	-20.8	2.5	***
Number of farms with both grain corn and soybeans and GM soybeans	1,400	1,864	33.1	2.91	***	116	212	82.8	1.83	***
Number of farms with grain corn and GM grain corn	1,951	1,698	-13.0	1.33	*	1,321	1,170	-11.4	1.04	ns
Number of farms with soybeans and GM soybeans	1,978	2,021	2.2	0.21	ns	209	147	-29.7	1.01	ns
Average acres of GM products per farm	86	103	18.9	5.43	***	92	137	49.0	2.04	**
Total acres of GM and non-GM crops on farms with GM crops	2,326,922	2,517,456	8.2	2.88	***	791,370	916,797	15.8	1.44	*
Average acres of GM and non-GM crops operated by GM Farms	219	240	9.5	3.11	***	229	290	26.7	2.43	***
Percent GM acres of total acres for GM growers	39	43	8.6	3.18	***	40	47	17.6	1.54	*

T-test: T test Student value
***: Significantly different at 1% **: Significantly different at 5%; *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

This supports the earlier observation that, in 2001, GM soybeans appear to have attracted the attention of farmers to a greater extent than has been the case with GM grain corn. That may have simply been a reflection of farmer price expectations in the spring of 2001 with respect to corn prospects and expected returns.

However, in the United States, GM soybeans also appear to have attracted farmers' attention to a greater extent than has GM grain corn, particularly in 1998 (Economic Research Service, 2001). That year, the planted area of the Herbicide-Tolerant Soybeans was around 44.2% of the total, compared with 37.5% for Bt Corn and Herbicide-Tolerant Corn together. Herbicide-Tolerant Soybeans were nearly 70% of the planted acreage in 2001 (Williams, L. et al., 2001a). The Starlink Corn variety incident[5] (Williams, L. et al., 2001b) can explain slow expansion of GM grain corn in 2001 compared to GM soybeans. With the incident, U.S. corn exports were disrupted, leading grain corn prices down and probably putting a brake on GM grain corn expansion for Canadian farmers.

Farmers growing only soybeans, and who reported having GM soybeans, increased their area by only 2.2% in Ontario but decreased it by 29.7% in Quebec (Table 2). It may be that farmers with

[5] Starlink is a GM Corn variety approved for animal feed but not for industrial uses and human consumption. Starlink corn contains the Cry9C protein which is toxic to European corn borers and certain other insect pests. In 2000, a testing lab indicated the presence of the Cry9C protein in a sample of Taco Bell taco shells. This incident led to the recall of hundreds of food products and corn shipments.

only grain corn or soybeans are still hesitating to adopt GM technology, probably because of anticipated risks about GM crop market or return.

Commodity and Province Profile

In Ontario, the area of GM grain corn and soybeans grew strongly from 2000 to 2001 GM soybean area increased 25.4%, and GM grain corn area, 11.3% (Table 3). The number of farms reporting GM grain corn has fell a sharp 8.7%, but the number of farms growing GM soybeans jumped 12.2%.

On Ontario farms that seeded GM crops, both the GM and non-GM areas of grain corn and soybeans expanded from 2000 to 2001. The average area of GM grain corn and GM soybeans per farm reporting seeding GM crops also increased. However, the land seeded to grain corn and soybeans by farmers who reported seeding GM crops rose for grain corn but fell slightly for soybeans. This means that the GM area increase in grain corn is mainly the result of existing GM growers expanding their GM area, and not new GM producers. However, for soybeans, the GM area increase in 2001 appears to be influenced mainly by farmers who decided to grow GM soybeans for the first time, and secondarily by existing producers who increased their GM crop area.

Table 3. Changes in GM Farms by Commodity, Ontario

	Grain corn					Soybeans				
	2000	2001	Change	T-test	P-value	2000	2001	Change	T-test	P-value
Total acres of GM products	510,986	568,574	11.3	2.61	***	407,221	510,483	25.4	4.6	***
Total number of farms reporting GM products	7,255	6,622	-8.7	2.61	***	5,740	6,439	12.2	2.4	***
Average acres of GM products per farm	70.4	85.9	21.9	5.26	***	71	79	11.7	2.8	***
Total acres of GM products and non-GM crops operated on GM farms	954,428	1,022,611	7.1	1.98	**	810,505	893,740	10.3	2.28	**
Average acres of GM and non-GM crops operated on GM farms	132	154	17.4	4.53	***	141	139	-1.7	0.42	ns
Percent of GM acres of total acres for GM growers	54	56	3.9	1.39	*	50	57	13.7	3.6	***
Total acres of non-GM product farms	925,624	949,498	2.6	0.72	ns	1,510,534	1,282,525	-15.1	5.35	***
Number of non-GM farms	11,528	10,782	-6.5	1.99	**	13,025	11,642	-10.6	3.93	***
Average acres per non-GM farms	80	88	10.0	3.01	**	116	110	-5.0	2.0	**
Percent of GM acres of total GM and non-GM acres	27	29	6.0	1.55	*	18	23	34.0	6.0	***

T-test: T test Student value
***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

In Quebec, GM area jumped 30.3% for grain corn and 63.0% for soybeans from 2000 to 2001. As was the case in Ontario, the number of farms in Quebec reporting GM grain corn fell 10.6%, but the number of farms reporting GM soybeans rose 11.0%; this increase, however, was not statistically significant (Table 4). Among farms that reported GM crops, the average total area of grain corn and soybeans increased, as well as the percentage of GM area for both crops.

Table 4. Changes in GM Farms by Commodity and Province, Quebec

	Grain corn					Soybeans				
	2000	**2001**	**Change**	**T-test**	**P-value**	**2000**	**2001**	**Change**	**T-test**	**P-value**
Total acres of GM products	259,705	338,373	30.3	1.55	*	57,934	94,448	63.0	1.46	*
Total number of farms reporting GM products	3,138	2,806	-10.6	1.85	**	940	1,043	11.0	0.89	ns
Average acres of GM products per farm	83	121	45.7	2.29	**	62	91	46.9	1.34	*
Total acres of GM products and non-GM crops operated on GM farms	570,344	641,451	12.5	1.18	ns	96,774	123,493	27.6	1.07	ns
Average acres of GM and non-GM crops operated on GM farms	182	229	25.8	2.45	***	103	118	15.0	0.71	ns
Percent of GM acres of total acres for GM growers	46	53	15.8	1.75	**	60	76	27.8	2.57	***
Total Acres of non-GM products farms	403,028	458,466	13.8	2.15	**	251,125	230,410	-8.2	1.24	ns
Number of non-GM farms	4,174	4,358	4.4	0.88	ns	3,172	2,989	-5.8	1.16	ns
Average acres per non-GM farms	97	105	9.0	1.62	*	79	77	-2.6	0.42	ns
Percent of GM acres of total GM and non-GM acres	27	31	15.3	1.22	ns	17	27	60.3	1.84	**

T-test: T test Student value
***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Farm Size Comparisons

The number of large farms reporting GM increased significantly from 2000 to 2001, and the total area of GM grown on large farms has risen for both grain corn and soybeans, in Quebec and Ontario. The average area of GM grain corn and soybeans per farm grew sharply for all farm size categories; large farms reported the greatest increase. The share of total GM area found on small and medium farms decreased, but was more than offset by significant gains in area grown by large farms. This farm category made a large contribution to the increase in total GM area (Tables 6 and 5, Appendix 2).

In Ontario, the number of small farms reporting GM grain corn dropped a significant 11.5%. The proportion of small farms growing GM crops compared with all small farms has also fell 2.6%. To further complicate matters, survey estimates also show that, from 2000 to 2001, farms classified as small have declined in proportion to total farm numbers.

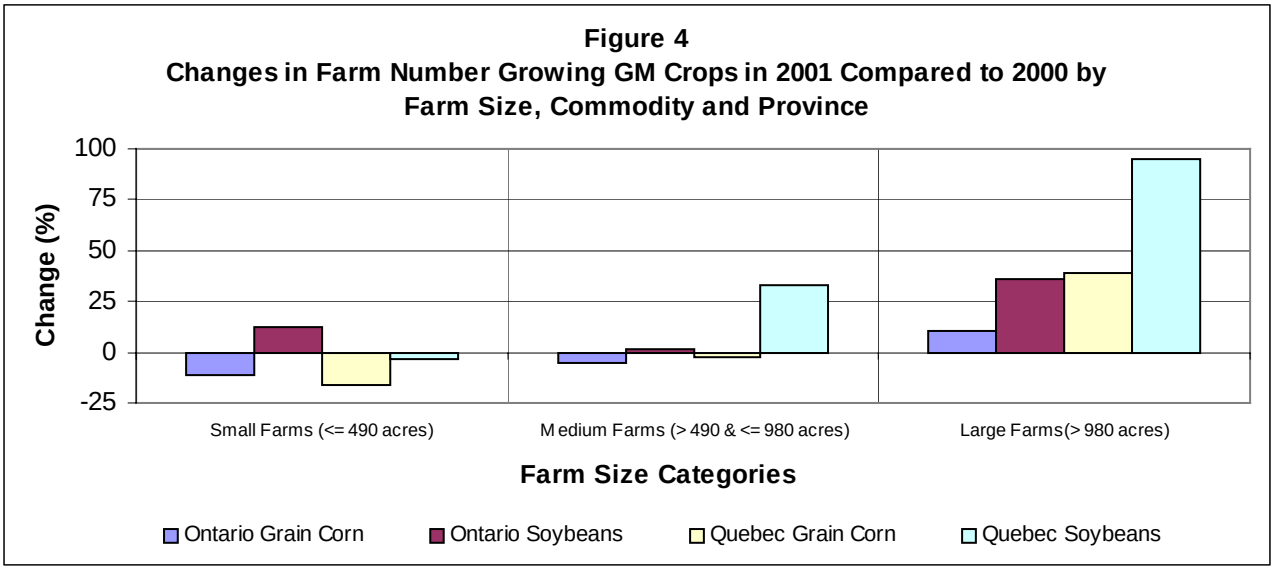
The situation with respect to GM soybeans is different. The number of farms reporting GM area and the proportion of farms reporting GM crops in relation to all farms reporting soybeans increased irrespective of farm size. The gains are statistically significant for farms classified as small and large, indicating that GM crops are gaining popularity among farmers, regardless of farm size.

U.S. farmers reported the same trend. According to the results of a survey conducted involving more than 300 Iowa farmers, GM crops have been gaining popularity among U.S. farmers, although not for economic reasons (Duffy, M. and Ernest, M., 2000).

Farms reporting GM soybeans as a proportion of all farms growing GM crops decreased for both small and medium farms. The proportion of large farms to all farms reporting GM crops jumped a significant 21.5%.

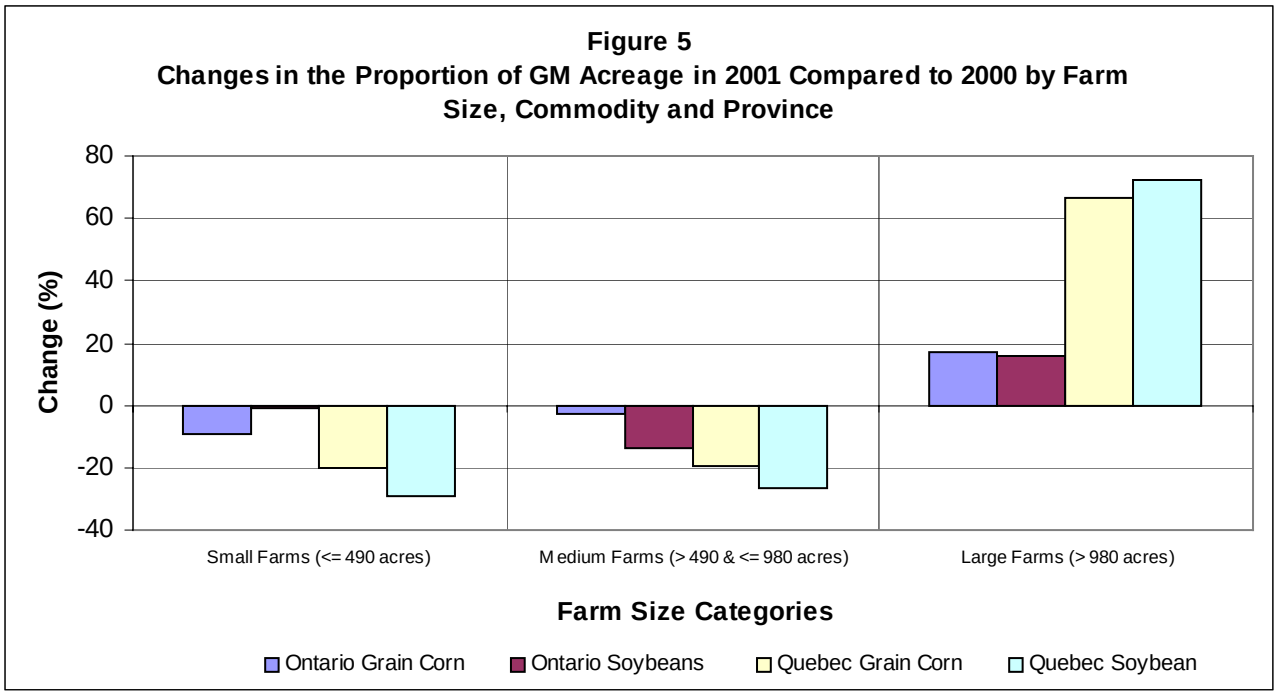
The total area of GM soybeans in Ontario rose sharply on both small (24.0%) and large (45.5%) farms. Despite the increase in land seeded to GM grain corn and soybeans, the proportion of total area seeded to GM crops declined on both small and medium farms (Figure 4).

Figure 4
Changes in Farm Number Growing GM Crops in 2001 Compared to 2000 by Farm Size, Commodity and Province



Source: Statistics Canada, Agriculture Division, June Farm Surveys, 2000 and 2001.

Ontario farms classified as large expanded their soybean area 45.5%. They also increased their proportion of total GM area in relation to all other size categories by 16.1%. Farms of all sizes contributed to the increase in the GM soybean area in 2001, but the large farms played a major role in the increase. Compared with 2000, this indicates a gain of interest of large farms in GM crops (Table 5, Appendix 2, Figure 5).



Source: Statistics Canada, Agriculture Division, June Farm Surveys, 2000 and 2001.

In Quebec, the GM soybean area increased as in Ontario. Large farms seeded the largest proportion of the increase in the GM area—more than double the GM crop in 2000. The trend for grain corn was similar (Table 6, Appendix 2, Figure 5). In Quebec, large farms accounted for the largest percentage of GM grain corn area, 38.6%, and the largest percentage of GM soybean area, 48.4%. The percentage of GM area held by Quebec's large farms has risen 66.7% for grain corn and 77.2% for soybeans from 2000 to 2001 (Table 6, Appendix 2).

The survey data for 2000 and 2001 show that more Ontario and Quebec farmers are adopting GM crops. It also appears that, as farmers gain more experience in growing GM crops, operators of large farms have become much more interested in GM grain corn and soybeans than they were in the first few years that the seeds came on the market. This is a different portrait of the GM growers identified in the 2000 survey, who tended to be drawn largely from among the operators of what would normally be categorized as small to medium farms. That large farms are pulling ahead in the race to adopt GM crops can be interpreted as a sign of the end of the experimental phase in GM grain corn and soybean crops.

Regional Comparisons

In Quebec, increases in area of the GM grain corn were significant in two regions (9 and 13). However, GM grain corn area actually decreased in the other two regions (4 and 7). Although the total number of farms using GM grain corn dropped slightly, region 9 increased its number of GM farms. Area in GM soybean rose substantially in all regions, but growth was more noticeable in Region 7 and particularly Region 9, where GM soybean area more than quadrupled

in 2001. The higher number of Quebec farms in 2001 (up 9.0% from 2000) with GM soybean only partly explains this sharp rise in GM soybean area; much of the increase originated from farmers who already used GM soybean in 2000 expanding their GM area in 2001 (Table 8a and 8b Appendix 2).

In Ontario, the increase in GM grain corn area was mainly the result of a larger area sown by farmers who had grown GM grain corn in 2000. GM soybean area grew in 2001 because of both greater area sown by farmers who had grown GM soybeans in 2000 and more first-time GM soybean farmers, especially in Region 4 (Table 7a and 7b; Appendix 2).

The regression coefficients show that, in Ontario, as farmers increased their area of total grain corn, there was a corresponding increase in the area in GM corn. The situation for Ontario grain corn was similar to the pattern observed for Quebec soybeans (Table 9, Appendix 2).

Yield Comparisons

GM and non-GM Yield Comparisons

The Statistics Canada November Farm Survey reported that, generally, GM grain corn and soybean crops yielded more than non-GM varieties. According to the farmers surveyed in 2001, GM varieties yielded more than non-GM for both grain corn and soybeans in Ontario and Quebec. (Tables 10a, 10b, 11a and 11b, Appendix 2). This was the case across all farm sizes, the exception being grain corn grown on small Ontario farms. (Table 14a and 14b, Appendix 2).

In Ontario, GM grain corn yields were similar in 2000 and 2001. Yield for non-GM grain corn was lower in 2001 than in 2000 (Table 10a, Appendix 2). In Ontario, GM grain corn yielded 4.8 bushels per acre more than non-GM in 2000 and 7.8 bushels more in 2001.

In Quebec, the GM grain corn yield in 2001 was 18.7 bushels per acre greater than in 2000. That year was a poor one for grain corn in Quebec because of a dry spring followed by relatively cool and wet weather for the rest of the growing season. The GM grain corn yield was 11.5 bushels per acre more than non-GM grain corn in 2000, but in 2001, non-GM yields were 2.6 bushels per acre higher than GM yields (Table 11b, Appendix 2). We do not have a good explanation of why respondents to the 2001 survey reported better yields from non-GM grain corn compared with GM varieties. Farmer responses from the November 2001 Farm Survey also indicated substantial variation among agricultural regions (Tables 10a and 10b, Appendix 2). This variation was surprising, particularly the information that non-GM yields in some regions were higher than those for GM varieties. It may have been related to the response of the GM varieties to what were relatively dry crop conditions in the middle of the growing season.

For soybeans, the 2001 growing season produced one of the worst yields on record for Ontario. Unlike Ontario grain corn however, GM soybeans yielded more than non-GM soybeans in both 2000 and 2001. Yields varied substantially among agricultural regions, as was the case for grain corn (Table 11a, Appendix 2).

In Quebec, the GM soybean yields in 2000 and 2001 were similar. At the provincial level, soybean yields for non-GM varieties were 1.8 bushels per acre less than GM varieties in 2001,

but again there was substantial variation among regions. The GM yields were always higher than those of the non-GM varieties; 1.6 bushels per acre in 2000 and 3.5 bushels per acre in 2001.

Impact of GM Crop Varieties on Provincial Grain Corn and Soybean Production

In an effort to measure the impact of GM grain corn on average provincial yields, we compared the average yields of grain corn growers who had planted their entire grain corn area with GM seed to those growers who had used both GM grain corn and regular grain corn, as well as to those of growers who had planted regular corn only.

Grain Corn Yield

The findings show that, at the provincial level, in Quebec and Ontario, average grain corn yields for (1) farmers planting GM grain corn and (2) farmers planting both non-GM and GM varieties, yields were higher than the yields for farmers who reported growing only non-GM grain corn. This was the case in both 2000 and 2001. The GM techonology seems to have a positive impact on average yield per farm. This was a particularly interesting observation, as the grain corn growing conditions were quite different between the two years. In Ontario, conditions in 2000 were distinctly better than 2001; in Quebec, 2001 was clearly the better year (Table 12 and Table 12b, Appendix 2).

Soybean Yield

In Ontario, the 2001 soybean crop was one of the worst on record for all farms in all parts of the province (Table 13a, Appendix 2). At the provincial level, farms who grew only GM soybeans had better yields (1.9 bushels per acre) than farms growing only non-GM soybeans (Table 13a).

In Quebec, farms with only GM soybeans reported better yields in 2001 than in 2000 compared with those who grew a mix of GM and regular soybeans and those who grew only regular soybeans. This is true in all the agricultural regions except Region 13 where, even though the 2001 yield was lower than that in 2000, the decrease was smaller for farms with only GM soybeans (Table 13b, Appendix 2). In both 2000 and 2001, yields obtained by farmers growing only GM soybeans were higher than those obtained by farmers growing only non-GM soybeans—the difference was 14.4 bushels per acre. in 2001. In 2000, with poorer growing conditions, the difference was a smaller 2.3 bushels per acre (Table 13b, Appendix 2).

One should not always expect higher yields with GM grain corn and soybeans. The impact of GM grain corn will be related to corn borer infestation. If there is little corn borer injury with non-GM grain corn, yield advantage with GM grain corn should be limited. For Roundup Ready soybeans, weed control is the primary issue. However, if weeds are controlled well with non-GM soybeans, and without significant herbicide injury to the plants, then GM and non-GM yields should be about the same. The yield of GM soybeans should be better only if Roundup Ready soybeans and the use of the Roundup herbicide is the better means for weed control. It has been shown that GM grain corn varieties may not be economical unless corn borer pressure is high (Mark Sears and Art Schaafsma, 2001).

Yields by Commodity and Farm Size

In 2001, non-GM grain corn yielded more than GM grain corn in Quebec. The situation was reversed in Ontario (Table 14a, Appendix 2). Most of the variation in grain corn yields was observed among medium farms in both provinces.

Even though the 2001 growing season was less favorable, GM soybeans yielded more than non-GM soybeans (Table 14b, Appendix 2). Soybean yields similar to those of grain corn varied widely among farms classified as medium in both provinces.

Conclusion and Outlook

Preliminary work suggests that GM crops do not guarantee better yields and that farmers may not always capture economic benefits from them. Based on Statistics Canada's Farm Surveys, land seeded to GM varieties of grain corn and soybeans has increased in Quebec and in Ontario. The increase in GM area was due to existing GM growers increasing their GM seeded area as well as other farmers who had never grown GM crops seeding GM varieties for the first time in 2001. The increase in GM soybean area was substantial, especially in Quebec. Although the early adopters of GM grain corn and soybeans appeared to be largely the operators of small farms, large farmers appear to have been quick to recognize what appears to be a successful innovation. Operators of large farms have paid attention to the results of GM crop adoption by smaller operators, and have now themselves seeded significant amounts of land and become responsible for a significant amount of GM crop production.

The Statistics Canada November Farm Survey data show that, GM yields for soybeans and grain corn have been generally better than non-GM yields. However, this is not an assurance of better yields; under certain conditions GM crops may deliver lower yields than other varieties. GM crop varieties appear to boost yields for both grain corn and soybean crops.

It will be interesting to analyze this trend over the long term and further investigate the economic implications for agriculture. As GM crops gain popularity in the coming years, it will be interesting to collect data on such aspects as:

- the reasons for GM crop adoption
- the costs and net returns of GM crops
- whether GM crops reduce the use of pesticides
- differences in prices of GM crops compared with other varieties
- the characteristics of the GM grain corn and GM soybean markets.

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APPENDIX 1. Variance Calculation Formulae

Variance of the Difference between Totals

Variance estimates for the change from 2000 to 2001 have been calculated through the steps below.

The estimate for a total $\hat{y}_t$ (area or number of farms) for a given growing season *t* have been calculated as follow[6]:

$$\hat{Y}_t = \sum_{h=1}^{L}\sum_{k=1}^{n_h} w_{thk}\, y_{thk}(d)$$

Where $y_{thk}(d) = \begin{cases} y_{thk} \text{ if farm } k \text{ in the stratum } h \text{ belongs to domain } d \\ 0 \text{ otherwise} \end{cases}$

And w_{thk} represent the adjusted weighted of farm *k* of n_h farms in the stratum *h* of *L* strata.

The variance of $\hat{Y}_1 - \hat{Y}_2$ is estimated by $\hat{V}(\hat{Y}_1 - \hat{Y}_2) = \hat{V}(\hat{Y}_1) + \hat{V}(\hat{Y}_2) - 2Cov(\hat{Y}_1, \hat{Y}_2)$

Where $\hat{V}(\hat{Y}_t) = \sum_{h=1}^{L}\left(1 - \frac{n_{th}}{N_{th}}\right)\frac{n_{th}}{n_{th}-1}\sum_{k=1}^{n_{th}}(w_{thk}\, y_{thk}(d) - \bar{y}_{th}(d))^2$, nth represent

$$\bar{y}_{th}(d) = \frac{1}{n_{th}}\sum_{k=1}^{n_{th}} w_{thk}\, y_{thk}(d),$$

$$Cov(\hat{Y}_1, \hat{Y}_2) = \sum_{h=1}^{L}\left(1 - \frac{n_h^*}{\min(N_{1h}, N_{2h})}\right)\frac{n_h^*}{n_h^* - 1}\sum_{k=1}^{n_h^*}(w_{1hk}\, y_{1hk}(d) - \bar{y}_{1h}^*(d))(w_{2hk}\, y_{2hk}(d) - \bar{y}_{2h}^*(d)),$$

$$\bar{y}_{th}^*(d) = \frac{1}{n_h^*}\sum_{k=1}^{n_h^*} w_{thk}\, y_{thk}(d),$$

And n_h^* represent the overlap of the two samples.

Variance of the Difference between Ratios

The ratio for the period *t* is estimated by $\hat{R}_t = \frac{\hat{Y}_t}{\hat{X}_t} = \frac{\sum_{h=1}^{L}\sum_{k=1}^{n_h} w_{thk}\, y_{thk}(d)}{\sum_{h=1}^{L}\sum_{k=1}^{n_h} w_{thk}\, x_{thk}(d)}$,

Where $y_{thk}(d) = \begin{cases} y_{thk} \text{ if farm } hk \text{ belongs to the domain} \\ 0 \text{ otherwise} \end{cases}$

[6] Formulas adapted by Milorad Kovacevic and Owen Phillips from Methods presented in Roberts et al., 2001 to suit a rotating panel design. Methodologist, Social Survey Methods Division (SSMD), Statistics Canada

And $x_{thk}(d) = \begin{cases} x_{thk} \text{ if farm } hk \text{ belongs to the domain} \\ 0 \text{ otherwise} \end{cases}$

Because the numerator and the denominator are both sample estimates, the Taylor linearization has been used to approximate the variance of the ratio change.

Then we approximate the variance of $\hat{R}_1 - \hat{R}_2$ by $\hat{V}(\hat{Z}_1 - \hat{Z}_2)$

Where $\hat{Z}_t = \sum_{h=1}^{L} \sum_{k=1}^{n_{th}} w_{thk} z_{thk}(d),$

And $z_{thk}(d) = \frac{(y_{thk}(d) - \hat{R}_t x_{thk}(d))}{\hat{X}_t},$

The variance is estimated by $\hat{V}(\hat{Z}_1 - \hat{Z}_2) = \hat{V}(\hat{Z}_1) + \hat{V}(\hat{Z}_2) - 2Cov(\hat{Z}_1, \hat{Z}_2)$

Where $\hat{V}(\hat{Z}_t) = \sum_{h=1}^{L} \left(1 - \frac{n_{th}}{N_{th}}\right) \frac{n_{th}}{n_{th} - 1} \sum_{k=1}^{n_{th}} (w_{thk} z_{thk}(d) - \bar{z}_{th}(d))^2,$

$\bar{z}_{th}(d) = \frac{1}{n_{th}} \sum_{k=1}^{n_{th}} w_{thk} z_{thk}(d),$

$Cov(\hat{Z}_1, \hat{Z}_2) = \sum_{h=1}^{L} \left(1 - \frac{n_h^*}{\min(N_{1h}, N_{2h})}\right) \frac{n_h^*}{n_h^* - 1} \sum_{k=1}^{n_h^*} (w_{1hk} z_{1hk}(d) - \bar{z}_{1h}^*(d))(w_{2hk} z_{2hk}(d) - \bar{z}_{2h}^*(d)),$

And $\bar{z}_{th}^*(d) = \frac{1}{n_h^*} \sum_{k=1}^{n_h^*} w_{thk} z_{thk}(d).$

APPENDIX 2. Reference Tables

Table 5. Changes in Farms by Size and Commodity in Ontario

Parameters	Grain corn					Soybeans				
	2000	2001	Change	T-test	P-value	2000	2001	Change	T-test	P-value
Number of GM farms <= 490 acres	5,429	4,807	-11.5	2.23	**	4,391	4,918	12.0	1.86	**
Number of GM farms > 490 acres and <= 980 acres	1,220	1,149	-5.8	0.84	ns	916	932	1.7	0.18	ns
Number of GM farms > 980 acres	605	666	10.1	1.55	*	433	590	36.3	4.16	***
Number of non-GM farms <= 490 acres	9,615	8,874	-7.7	2.06	**	10,674	9,476	-11.2	3.48	***
Number of non-GM farms > 490 acres and <= 980 acres	1,441	1,387	-3.7	0.49	ns	1,659	1,593	-3.9	0.62	ns
Number of non-GM farms > 980 acres	473	524	11.0	1.09	ns	692	573	-17.2	2.32	**
Ratio of GM farms to total farms <= 490 acres (Ratio of number of farms)	36.1	35.1	-2.6	0.54	ns	29.1	34.2	17.2	2.9	***
Ratio of GM farms to total farms > 490 and <=980 acres	45.9	45.3	-1.2	0.19	ns	35.6	36.9	3.7	0.5	ns
Ratio of GM farms to total farms > 980 acres	56.2	56.0	-0.4	0.06	ns	38.5	50.7	31.9	4.0	***
Ratio of number of GM farms (<= 490 acres) to total number of GM farms	74.8	72.6	-3.0	1.54	*	76.5	76.4	-0.2	0.1	ns
Ratio of number of GM farms (>490 acres and <=980 acres) to total number of GM farms	16.8	17.4	3.2	0.42	ns	16.0	14.5	-9.4	1.1	ns
Ratio of number of GM farms (> 980 acres) to total number of GM farms	8.3	10.1	20.6	2.62	***	7.5	9.2	21.5	2.3	**
Ratio of number of all farms (<= 490 acres) to total number of all farms	80.1	78.6	-1.9	2.02	**	80.3	79.6	-0.8	1.0	ns
Ratio of number of all farms (> 490 acres and <= 980 acres) to total number of all farms	14.2	14.6	2.8	0.58	ns	13.7	14.0	1.8	0.4	ns
Ratio of number of all farms (> 980 acres) to total number of all farms	5.7	6.8	19.2	3.53	***	6.0	6.4	7.3	1.4	*
Total acres of GM farms <= 490 acres	240,033	242,048	0.8	0.13	ns	201,595	250,247	24.1	2.99	***
Total acres of GM farms > 490 acres and <= 980 acres	118,170	127,773	8.1	0.95	ns	103,981	112,342	8.0	0.69	ns
Total acres of GM farms > 980 acres	152,782	198,754	30.1	3.14	***	101,646	147,894	45.5	4.11	***
Average of GM acres for farms <= 490 acres	44	50	13.9	3.18	***	46	51	10.8	2.22	**
Average of GM acres for farms > 490 acres and <= 980 acres	97	111	14.8	2.48	***	113	121	6.3	0.70	ns
Average of GM acres for farms > 980 acres	252	298	18.2	2.41	***	235	251	6.8	0.85	ns
Ratio of GM farms (<= 490 acres) area to total area of GM farms	47.0	42.6	-9.4	2.09	**	49.5	49.0	-1.0	0.2	ns
Ratio of GM farms (> 490 acres and < 980 acres) area to total area of GM farms	23.1	22.5	-2.8	0.37	ns	25.5	22.0	-13.8	1.5	*
Ratio of GM farms (> 980 acres) area to total area of GM farms	29.9	35.0	16.9	2.38	***	25.0	29.0	16.1	1.9	**

T-test: T test Student value
***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 6. Changes in Farms by Size and Commodity in Quebec

Parameters	Grain corn					Soybeans				
	2000	2001	Change	T-test	P-value	2000	2001	Change	T-test	P-value
Number of GM farms <= 490 acres	2,382	1,988	-16.5	2.30	**	696	672	-3.5	0.23	ns
Number of GM farms > 490 acres and <= 980 acres	559	544	-2.8	0.30	ns	168	223	32.8	1.77	**
Number of GM farms > 980 acres	197	274	39.1	1.64	*	76	148	94.8	1.96	**
Number of non-GM farms <= 490 acres	3,530	3,663	3.8	0.65	ns	2,483	2,263	-8.8	1.44	*
Number of non-GM farms > 490 acres and <= 980 acres	531	523	-1.5	0.12	ns	537	534	-0.7	0.06	ns
Number of non-GM farms > 980 acres	113	173	52.3	2.11	**	152	193	26.9	1.45	*
Ratio of GM farms to total farms <= 490 acres (Ratio of number of farms)	40.3	35.2	-12.7	1.90	**	21.9	22.9	4.5	0.31	ns
Ratio of GM farms to total farms > 490 and <= 980 acres	51.3	51.0	-0.7	0.08	ns	23.8	29.5	23.8	1.40	*
Ratio of GM farms to total farms > 980 acres	63.5	61.3	-3.4	0.30	ns	33.4	43.5	30.2	1.28	*
Ratio of number of GM farms (<= 490 acres) to total number of GM Farms	75.9	70.9	-6.6	2.17	**	74.0	64.4	-13.0	2.12	**
Ratio of number of GM farms (> 490 acres and <= 980 acres) to total number of GM farms	17.8	19.4	8.7	0.82	ns	17.9	21.4	19.7	1.03	ns
Ratio of number of GM farms (> 980 acres) to total number of GM farms	6.3	9.8	55.5	2.19	**	8.1	14.2	75.5	1.84	**
Ratio of number of non-GM farms (<= 490 acres) to total number of all farms	80.8	78.9	-2.4	1.72	**	77.3	72.8	-5.9	2.60	***
Ratio of number of non-GM farms (> 490 acres and <= 980 acres) to total number of all farms	14.9	14.9	-0.1	0.02	ns	17.1	18.8	9.4	1.07	ns
Ratio of number of non-GM farms (> 980 acres) to total number of all farms	4.2	6.2	46.9	2.97	***	5.5	8.5	52.5	2.67	***
Total acres of GM farms <= 490 acres	124,589	129,358	3.8	0.42	ns	25,789	29,686	15.1	0.90	ns
Total acres of GM farms > 490 acres and <= 980 acres	75,048	78,521	4.6	0.44	ns	15,871	19,062	20.1	1.14	ns
Total acres of GM farms > 980 acres	60,068	130,494	117.2	1.42	*	16,276	45,700	180.8	1.20	ns
Average number of GM acres for farms <= 490 acres	52	65	24.4	3.8	***	37	44	19.3	2.3	**
Average number of GM acres for farms > 490 acres and <= 980 acres	134	144	7.6	0.8	ns	94	85	-9.6	0.7	ns
Average number of GM acres for farms > 980 acres	305	476	56.2	1.3	*	214	308	44.2	0.8	ns
Ratio of GM farms (<= 490 acres) area to total area of GM farms	48.0	38.2	-20.3	1.6	*	44.5	31.4	-29.4	1.3	ns
Ratio of GM farms (> 490 acres and <= 980 acres) area to total area of GM farms	28.9	23.2	-19.7	1.3	*	27.4	20.2	-26.3	1.0	ns
Ratio of GM farms (> 980 acres) area to total area of GM farms	23.1	38.6	66.7	1.6	*	28.1	48.4	72.2	1.3	ns

T-test: T test Student value
***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant.

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 7a. Changes in GM Area by Agricultural Region in Ontario

	Grain corn					Soybeans				
	2000	**2001**	**Change**	**T-test**	**P-value**	**2000**	**2001**	**Change**	**T-test**	**P-value**
Region 1	234,277	254,409	8.6	1.36	*	216,497	275057	27.0	3.21	***
Region 2	162,902	193,195	18.6	2.25	**	117,459	138371	17.8	1.92	**
Region 3	59,327	62,708	5.7	0.48	ns	44,387	48542	9.4	0.76	ns
Region 4	53,856	58,158	8.0	0.74	ns	27,416	47861	74.6	4.33	***

T-test: T test Student value
*** Significantly different at 1% ** Significantly different at 5% * Significantly different at 10% ns Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 7b. Changes in GM Farm Number by Agricultural Region in Ontario

	Grain corn					Soybeans				
	2000	**2001**	**Change**	**T-test**	**P-value**	**2000**	**2001**	**Change**	**T-test**	**P-value**
Region 1	3,111	2,836	-8.8	1.41	*	3,166	3,380	6.8	0.98	ns
Region 2	2,576	2,357	-8.5	1.21	ns	1,595	1,782	11.7	1.21	ns
Region 3	771	670	-13.1	1.38	*	469	498	6.2	0.44	ns
Region 4	787	756	-3.9	0.38	ns	479	748	56.2	3.61	***

T-test: T test Student value
***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 8a. Changes in GM Area by Agricultural Region in Quebec

	Grain corn					Soybeans				
	2000	**2001**	**Change**	**T-test**	**P-value**	**2000**	**2001**	**Change**	**T-test**	**P-value**
Region 4	37,923	28,961	-23.6	1.82	**	13,767	14,565	5.8	0.27	ns
Region 7	16,316	13,721	-15.9	1.05	ns	5,220	9,193	76.1	2.62	***
Region 9	3,965	7,319	84.6	1.81	**	1,170	6,218	431.5	2.34	***
Region 13	190,732	281,146	47.4	1.80	**	37,354	63,132	69.0	1.05	ns

T-test: T test Student value
***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 8b. Changes in GM Farm Numbers by Agricultural Region in Quebec

	Grain corn					Soybeans				
	2000	**2001**	**Change**	**T-test**	**P-value**	**2000**	**2001**	**Change**	**T-test**	**P-value**
Region 4	510	450	-11.8	0.67	ns	208	220	5.8	.26	ns
Region 7	229	188	-17.9	1.10	ns	61	116	90.2	2.06	**
Region 9	63	92	46.0	.99	ns	25	44	76.0	1.46	*
Region 13	2029	1903	-6.2	.71	ns	630	630	0.0	.01	ns

T-test: T test Student value
***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 9. Regression of the Difference between 2001 and 2000 GM Area on the Difference between 2001 and 2000 Non-GM Area for Farms Having GM Grain Corn and/or GM Soybean in both Growing Seasons 2001 and 2000.

Province	Crops	Dependent variable	Weighted mean of dependent variable (acres)	Independent variable and effect	BETA	SE	T: BETA=0	P-value
Ontario	Grain corn	$d260_{01\text{-}00}$	14.9 (17.9)	Intercept	7.75	3.15	2.46	**
				$d216_{01\text{-}00}$	0.40	0.06	6.25	***
	Soybean	$d261_{01\text{-}00}$	-18.05 (-1.8)	Intercept	-17.93	4.49	3.99	***
				$d228_{01\text{-}00}$	0.07	0.15	0.43	ns
Quebec	Grain corn	$d260_{01\text{-}00}$	5.4 (-6.2)	Intercept	9.59	8.31	1.15	ns
				$d216_{01\text{-}00}$	0.68	0.47	1.43	ns
	Soybean	$d261_{01\text{-}00}$	-20.5 (-21.5)	Intercept	3.37	9.70	0.35	ns
				$d261_{01\text{-}00}$	1.11	0.45	2.47	**

$d260_{01\text{-}00}$: 2001 GM grain corn area – 2000 GM grain corn area
$d261_{01\text{-}00}$: 2001 GM soybean area – 2000 GM soybean area
$d216_{01\text{-}00}$: 2001 non-GM grain corn area – 2000 non-GM grain corn area
$d228_{01\text{-}00}$: 2001 non-GM soybean area – 2000 non-GM soybean area
BETA: regression coefficient
T: BETA: T-test of Student
SE: standard error
***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 10a. Comparison of Average GM and Non-GM Grain-Corn Yields, Based on Area, Ontario

Level of Analysis	Group	2000	2001	**Difference between 2001 and 2000**	**Yield Difference between GM and Non-GM in 2000**	**Yield Difference between GM and Non-GM in 2001**
Province:	GM	109.0	109.1	0.1	**4.8**	**7.8**
	Non-GM	104.2	101.3	-2.9		
	Mean	**105.6**	**103.4**	**-2.2**		
Region 1[11]	GM	118.4	111.2	-7.2	4.6	11.0
	Non-GM	113.8	100.2	-13.6		
Region 2	GM	108.1	112.4	4.3	7.1	4.9
	Non-GM	101.0	107.5	6.5		
Region 3	GM	98.6	90.2	-8.4	2.0	10.1
	Non-GM	96.6	80.1	-16.5		
Region 4	GM	90.9	106.0	15.1	9.2	3.5
	Non-GM	81.7	102.5	20.8		

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

[11] Main grain corn-producing areas in Ontario and Quebec:

Ontario		**Quebec**	
Region No.	Area Name	Region No.	Area Name
1	Southern Ontario	4	Mauricie-Bois-Francs
2	Western Ontario	7	Lanaudière
3	Central Ontario	9	Laurentides
4	Eastern Ontario	13	Montérégie

Table 10b. Comparison of Average GM and Non-GM Grain Corn Yields, Based on Area, Quebec

Level of Analysis	Group	2000	2001	**Difference between 2001 and 2000**	**Yield Difference between GM and Non-GM in 2000**	**Yield Difference between GM and Non-GM in 2001**
Province:	GM	101.2	119.9	18.7	**11.5**	**-2.6**
	Non-GM	89.7	122.5	32.8		
	Mean	**95.6**	**121.9**	**26.3**		
Region 4	GM	81.9	132.8	50.9	6	6.1
	Non-GM	75.9	126.7	50.8		
Region 7	GM	80.9	105.4	24.5	3.2	-7.1
	Non-GM	77.7	112.5	34.8		
Region 9	GM	91.7	89.8	-1.9	22.8	5.5
	Non-GM	68.9	84.3	15.4		
Region 13	GM	105.6	120.1	14.5	7.9	-6.7
	Non-GM	97.7	126.8	29.1		

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 11a. Comparison of Average GM and Non-GM Soybean yields, Based on Area, Ontario

Level of Analysis	Group	2000	2001	**Difference between 2001 and 2000**	**Yield Difference between GM and Non-GM in 2000**	**Yield Difference between GM and Non-GM in 2001**
Province	GM	39.0	21.7	-17.3		
	Mean	**38.0**	**20.9**	**-17.1**	**1.0**	**0.8**
Region 1[11]	GM	40.7	21.3	-19.4	1.1	0.8
	Non-GM	39.6	20.5	-19.1		
Region 2	GM	37.2	22.5	-14.7	-0.3	1.8
	Non-GM	37.5	20.7	-16.8		
Region 3	GM	38.5	16.5	-22.0	8.5	0.0
	Non-GM	30.0	16.5	-13.5		
Region 4	GM	35.1	26.3	-8.8	0.9	-1.7
	Non-GM	34.2	28.0	-6.2		

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

[11] Main soybean-producing areas in Ontario and Quebec:

Ontario		**Quebec**	
Region No.	Region Name	Region No.	Region Name
1	Southern Ontario	4	Mauricie-Bois-Francs
2	Western Ontario	7	Lanaudière
3	Central Ontario	9	Laurentides
4	Eastern Ontario	13	Montérégie

Table 11b. Comparison of Average GM and Non-GM Soybean Yields, Based on Area, Quebec

Level of Analysis	Group	2000	2001	**Difference between 2001 and 2000**	**Yield Difference between GM and Non-GM in 2000**	**Yield Difference between GM and Non-GM in 2001**
Province	GM	38.6	38.7	0.1	**1.6**	**3.5**
	Non-GM	37.0	35.2	-1.8		
	Mean	**37.5**	**35.6**	**-1.9**		
Region 4	GM	33.4	42.0	8.6	5.0	5.5
	Non-GM	28.4	36.5	8.1		
Region 7	GM	36.5	33.4	-3.1	-1.5	-1.1
	Non-GM	38.0	34.5	-3.5		
Region 9	GM	28.8	27.3	-1.5	-3.5	-1.2
	Non-GM	32.3	28.5	-3.8		
Region 13	GM	40.5	40.6	0.1	-0.5	5.3
	Non-GM	41.0	35.3	-5.7		

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 12a. Comparison of Average Grain Corn Yields, Based on Overall Farm Yield , Ontario

Level of Analysis	Group	2000	2001	**Difference between 2001 and 2000**	**Yield Difference between GM and Non-GM in 2000***	**Yield Difference between GM and Non-GM in 2001***
Province	Non-GM AND GM	107.2	109.6	2.4	-2.4	-1.8
	GM	104.8	107.8	3.0	**2.6**	**10.2**
	Non-GM	102.2	97.6	-4.6	**5.0**	**12**
Region 1	Non-GM AND GM	116.6	114.5	-2.1	-8.2	-7.8
	GM	108.4	106.7	-1.7	**-4.8**	**11.5**
	Non-GM	113.2	95.2	-18.0	**3.4**	**19.3**
Region 2	Non-GM AND GM	107.0	114.9	7.9	0.3	2.8
	GM	107.3	117.7	10.4	**9.5**	**13.5**
	Non-GM	97.8	104.2	6.4	**9.2**	**10.7**
Region 3	Non-GM AND GM	99.9	77.8	-22.1	1.0	10.2
	GM	100.9	88.0	-12.9	**13.0**	**14.4**
	Non-GM	87.9	73.6	-14.3	**12.0**	**4.2**
Region 4	Non-GM AND GM	85.8	100.2	14.4	-0.7	-40.9
	GM	85.1	59.3	-25.8	**4.7**	**-40.7**
	Non-GM	80.4	100.0	19.6	**5.4**	**0.2**

[7]

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

[7] *: First row gives the yield difference between GM and GM and non-GM, the second row the yield difference between GM and non-GM and the third row, the yield difference between non-GM and GM and non-GM. Same remark valid for tables 12a, 12b, 13a, 13b.

Table12b. Comparison of Average Grain Corn Yields, based on Overall Farm Yield, Quebec

Level of Analysis	Group	2000	2001	**Difference between 2001 and 2000**	**Yield Difference between GM and Non-GM in 2000**	**Yield Difference between GM and Non-GM in 2001**
Province	Non-GM AND GM	96.8	122.5	25.7	0.5	0.3
	GM	97.3	122.8	25.5	**13.1**	**4.0**
	Non-GM	84.2	118.8	34.6	**12.6**	**3.7**
Region 4	Non-GM AND GM	78.8	124.8	46.0	10.9	17.9
	GM	89.7	142.7	53.0	**17.1**	**17.6**
	Non-GM	72.6	125.1	52.5	**6.2**	**-0.3**
Region 7	Non-GM AND GM	83.8	105.0	21.2	1.9	-10.0
	GM	85.7	95.0	9.3	**5.7**	**-20.0**
	Non-GM	80.0	115.0	35.0	**3.8**	**-10.0**
Region 9	Non-GM AND GM	95.3	83.8	-11.5	-17.0	-
	GM	78.3	0.0	-	**3.9**	-
	Non-GM	74.4	83.5	9.1	**20.9**	**0.3**
Region 13	Non-GM AND GM	102.8	125.7	22.9	2.8	-3.3
	GM	105.6	122.4	16.8	**13.1**	**-0.1**
	Non-GM	92.5	122.5	30.0	**10.3**	**3.2**

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 13a. Comparison of Average Soybean Yields, Based on Overall Farm Yield, Ontario

Level of Analysis	Group	2000	2001	**Difference between 2001 and 2000**	**Yield Difference between GM and Non-GM in 2000**	**Yield Difference between GM and Non-GM in 2001**
Province	Non-GM AND GM	38.1	21.6	-16.5	0.6	2.0
	GM	38.7	23.6	-15.1	**0.6**	**1.9**
	Non-GM	38.1	21.7	-16.4	**0.0**	**-0.1**
Region 1	Non-GM AND GM	40.2	20.3	-19.9	0.4	2.7
	GM	40.6	23.0	-17.6	**1.2**	**2.0**
	Non-GM	39.4	21.0	-18.4	**0.8**	**-0.7**
Region 2	Non-GM AND GM	36.6	21.9	-14.7	1.0	3.3
	GM	37.6	25.2	-12.4	**-1.0**	**3.0**
	Non-GM	38.6	22.2	-16.4	**-2.0**	**-0.3**
Region 3	Non-GM AND GM	32.1	17.0	-15.1	3.9	-2.2
	GM	36.0	14.8	-21.2	**5.2**	**-3.1**
	Non-GM	30.8	17.9	-12.9	**1.3**	**-0.9**
Region 4	Non-GM AND GM	35.4	29.4	-6.0	-1.3	-1.9
	GM	34.1	27.5	-6.6	**-0.1**	**-0.5**
	Non-GM	34.2	28.0	-6.2	**1.2**	**1.4**

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table13b. Comparison of Average Soybean Yields, Based on Overall Farm Yield, Quebec

Level of Analysis	Group	2000	2001	**Difference between 2001 and 2000**	**Yield Difference between GM and Non-GM in 2000**	**Yield Difference between GM and Non-GM in 2001**
Province	Non-GM AND GM	40.4	30.6	-9.8	-0.9	19.2
	GM	39.5	49.8	10.3	**2.3**	**14.4**
	Non-GM	37.2	35.4	-1.8	**3.2**	**-4.8**
Region 4	Non-GM AND GM	32.2	39.6	7.4	3.4	1.7
	GM	35.6	41.3	5.7	**4.2**	**5.1**
	Non-GM	31.4	36.2	4.8	**0.8**	**3.4**
Region 7	Non-GM AND GM	47.5	21.0	-26.5	-9.8	17.6
	GM	37.7	38.6	0.9	**-2.0**	**0.8**
	Non-GM	39.7	37.8	-1.9	**7.8**	**-16.8**
Region 9	Non-GM AND GM	40.2	21.1	-19.1	-13.4	13.6
	GM	26.8	34.7	7.9	**-7.7**	**6.9**
	Non-GM	34.5	27.8	-6.7	**5.7**	**-6.7**
Region 13	Non-GM AND GM	40.9	33.6	-7.3	0.3	5.9
	GM	41.2	39.5	-1.7	**0.0**	**4.3**
	Non-GM	41.2	35.2	-6.0	**-0.3**	**-1.6**

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

Table 14a. Changes in GM and Non-GM Grain Corn Yield by Province, and Farm Size

Farm size	GM Grain corn Yield (bushels / acre)			Non-GM Grain corn Yield (bushels / acre)			Yield Difference between GM and Non-GM in 2000		Yield Difference between GM and Non-GM in 2001	
	2000	2001	Difference between 2001 and 2000	2000	2001	Difference between 2001 and 2000				
Quebec										
Farms <= 490 acres	100.1	119.9	19.8	92.9	121.1	28.2	7.2	2.01 **	-1.2	0.34 ns
Farms > 490 acres and <= 980 acres	107.1	116.0	8.9	90.5	119.7	29.2	16.6	1.82 *	-3.7	0.69 ns
Farms > 980 acres	102.1	124.1	22.0	90.4	128.3	37.9	11.7	1.22 ns	-4.2	0.69 ns
Ontario										
Farms <= 490 acres	110.0	111.9	1.9	106.7	103.7	-3.0	3.3	1.87 *	8.2	2.65 ***
Farms > 490 acres and <= 980 acres	109.7	111.9	2.2	102.6	101.1	-1.5	7.1	2.46 **	10.8	2.33 **
Farms > 980 acres	109.0	104.1	-4.9	102.7	96.8	-5.9	6.3	1.54 ns	7.3	1.84 *

***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

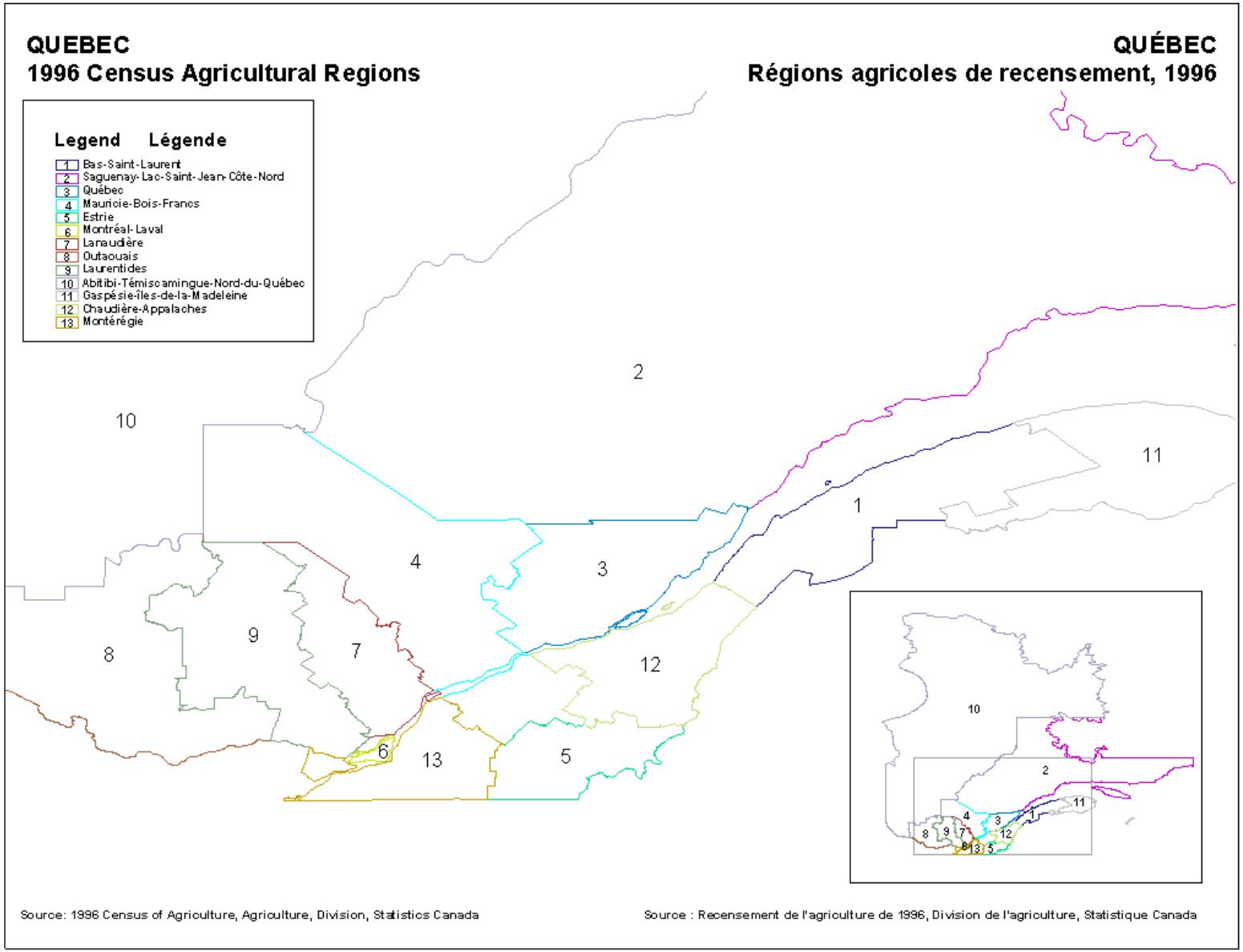
Table 14b. Changes in GM and Non-GM Soybean Yield by Province, Commodity and Farm Size

Farm size	GM Soybean Yield (bushels / acre)			Non-GM Soybean Yield (bushels / acre)			Yield Difference between GM and Non-GM in 2000		Yield Difference between GM and Non-GM in 2001	
	2000	2001	Difference between 2001 and 2000	2000	2001	Difference between 2001 and 2000		T-test		T-test
Quebec										
Farms <= 490 acres	39.6	37.3	-2.3	37.9	35.8	-2.1	1.7	1.01 ns	1.5	0.72 ns
Farms > 490 acres and <= 980 acres	37.4	37.5	0.1	37.0	34.3	-2.7	0.4	0.28 ns	3.2	1.85 *
Farms > 980 acres	38.1	38.1	0.0	34.9	35.4	0.5	3.2	0.65 ns	2.7	1.69 *
Ontario										
Farms <= 490 acres	38.9	22.3	-16.6	39.2	21.9	-17.3	-0.3	0.33 ns	0.4	0.66 ns
Farms > 490 acres and <= 980 acres	41.1	22.0	-19.1	39.0	20.5	-18.5	2.1	0.76 ns	1.5	1.51 ns
Farms > 980 acres	37.5	20.4	-17.1	35.3	19.4	-15.9	2.2	1.79 *	1.0	1.05 ns

***: Significantly different at 1% **: Significantly different at 5% *: Significantly different at 10% ns: Not significant

Source: Statistics Canada, Agriculture Division, calculated estimates from data of the 2000 and 2001 June Farm Surveys.

APPENDIX 3. Agricultural Regions of Ontario and Quebec (1996 Census of Agriculture)


QUEBEC
1996 Census Agricultural Regions
QUÉBEC
Régions agricoles de recensement, 1996
Legend Légende
1 Bas-Saint-Laurent
2 Saguenay-Lac-Saint-Jean-Côte-Nord
3 Québec
4 Mauricie-Bois-Francs
5 Estrie
6 Montréal-Laval
7 Lanaudière
8 Outaouais
9 Laurentides
10 Abitibi-Témiscamingue-Nord-du-Québec
11 Gaspésie-Îles-de-la-Madeleine
12 Chaudière-Appalaches
13 Montérégie
Source: 1996 Census of Agriculture, Agriculture, Division, Statistics Canada
Source : Recensement de l'agriculture de 1996, Division de l'agriculture, Statistique Canada

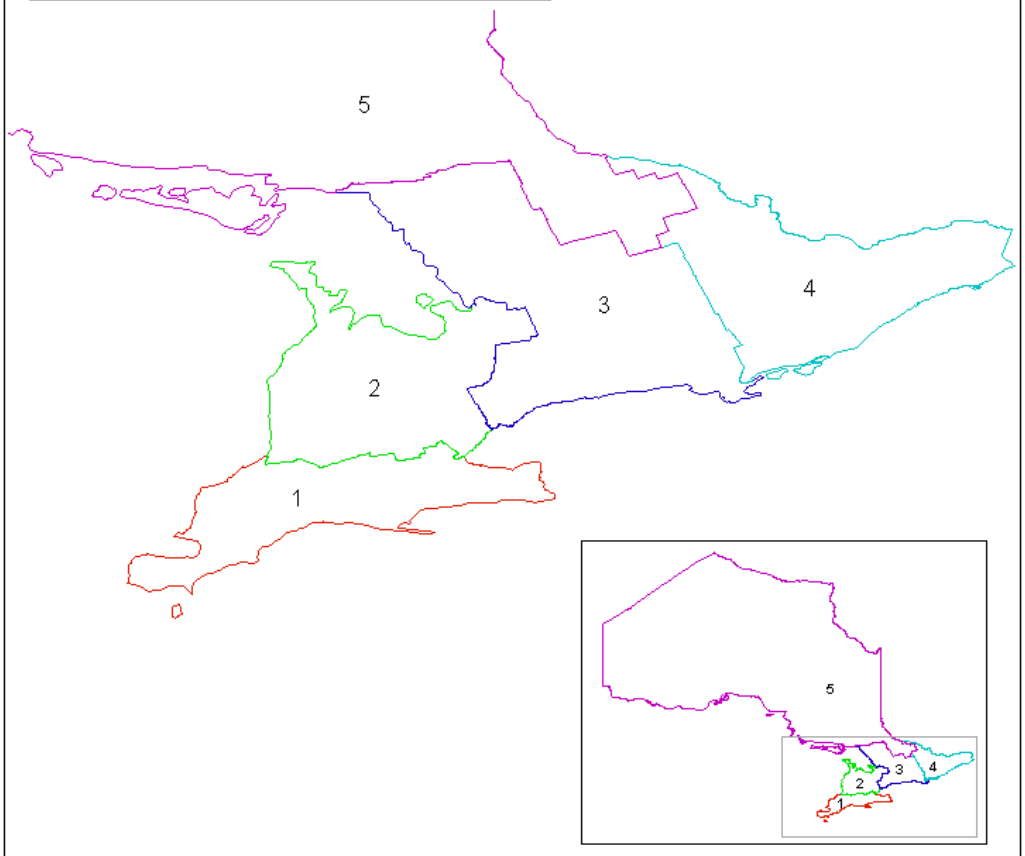
ONTARIO

1996 Census Agricultural Regions

ONTARIO

Régions agricoles de recensement, 1996

LEGEND	LÉGENDE
1 Southern Ontario Region	Région du Sud de l'Ontario
2 Western Ontario Region	Région de l'Ouest de l'Ontario
3 Central Ontario Region	Région du Centre de l'Ontario
4 Eastern Ontario Region	Région de l'Est de l'Ontario
5 Northen Ontario Region	Région du Nord de l'Ontario



Source: 1996 Census of Agriculture, Agriculture Division, Statistics Canada

Source : Recensement de l'agriculture de 1996, Division de l'agriculture, Statistique Canada

Agriculture and Rural Working Paper Series

(* Available at http://dissemination.statcan.ca/english/IPS/Data/21-601-MIE.htm**)**

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No.3	(21-601-MPE81003)	**A Review of the Livestock Estimating Project with Recommendations for the Future (1981)**, Bernard Rosien and Elizabeth Leckie
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No.5	(21-601-MPE84005)	**Preliminary Analysis of the Contribution of Direct Government Payments to Realized Net Farm Income (1984)**, Lambert Gauthier
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